‘Starquakes’ of Pulsar J0537
May Be Predictable

When John Middleditch of the Modeling, Algorithms and Information Group (CCS-3) started working on a paper for *Astrophysical Journal* about PSR J0537-6910 and the prediction of its “starquakes,” he had no idea how much interest his work would attract.

Only about 100 people looked at his poster at the American Astronomical Society meeting in Calgary, Canada, in early June 2006—but among those were “all the real pulsar people,” he recalled during a recent interview.

But a news release had gone out—and soon he started hearing from the media.

“Imagine the Universe News” ran an article on June 5.

NewScientist.com news service had one on June 6.

There was a front-page article in the June 9 Los Alamos Monitor.

There was a story in the June 19 issue of the Los Alamos National Laboratory Newsletter.

And the June 26 issue of the Department of Energy Pulse carried an item on his work.

“This is the story that refuses to die,” he said.

He continued working on his paper (co-authored with F.E. Marshall and W. Zhang of NASA/Goddard Space Flight Center, E.V. Gotthelf of Columbia University, and Q.D. Wang of the University of Massachusetts-Amherst)—but he was both surprised and pleased at the number of people who had already found his results fascinating.

Middleditch, who holds a doctorate in physics from the University of California-Berkeley, reports in his paper—“Predicting the Starquakes in PSR J0537-6910”—on the results of more than seven years of monitoring PSR J0537-6910, a pulsar/neutron star in the Large Magellanic Cloud. The data he is analyzing was acquired with the Rossi X-ray Timing Explorer.

During the time that he and his colleagues have been “watching” J0537 (as the 62 Hz pulsar is nicknamed), the pulsar has experienced 22 sudden increases in frequency. Each “glitch” is preceded by a series of small “jitters.” When the glitch occurs, the rate of spin of the pulsar increases slightly and then slows down again.

Strongly magnetized neutron stars—like J0537—are what remains after a massive star explodes. J0537 is a sphere approximately 20 miles across that contains 30% more mass than the Sun. Such stars are so dense that their electrons and protons are crushed together to form neutrons.

The dominant theory about starquakes in these stars—which are born spinning but gradually slow down—says that they have a solid crust that covers a "superfluid core" that flows without frictional resistance. The neutron star's magnetic field is locked into the solid crust and superfluid core and emits radiation that slows them down over time. But the superfluid deep within the solid crust does not slow with the rest of the pulsar. The two get out of synchronization. When the crust cracks, the disturbance dumps excess superfluid rotation into the solid crust, causing the pulsar to speed up again, and the process repeats.

J0537, associated with the 4,000-year-old supernova remnant N157B in a crowded stellar nursery called the Tarantula Nebula, is the most rapidly spinning young pulsar and the most frequently glitching pulsar known. In a few more years, J0537's observed glitches will outnumber those from all other pulsars combined.

By accumulating and analyzing data over many glitches, Middleditch and his colleagues believe they have detected a pattern and determined a way to predict when the next glitch in J0537 will occur.

As Middleditch says in the abstract of his paper, "The time interval from one glitch to the next obeys a strong linear correlation to the amplitude of the first glitch … such that these intervals can be predicted to within a few days, an accuracy which has never before been seen in any other pulsar." In other words, the time until the next glitch is proportional to the size of the previous glitch—and that time can be determined mathematically.

So what comes next? Middleditch said, "We'll keep observing until the spacecraft dies out."

He also noted that, "The X-ray photons themselves are at 3 to 20 kilovolts, and that is 1,000 to 7,000 times the energy of a blue photon. They go into the Proportional Counter Array and dump their energy. We could analyze the light curve of the pulsar. This light curve repeats itself every 16.1 milliseconds. We have enough data so that we could answer questions about how the light curve changes with X-ray photon energy. That could tell us a lot about the physical conditions of the space next to the pulsar where this is being generated."